

# Brief Communication: A Test and Correction of the Clavicle Method of Stout and Paine for Histological Age Estimation of Skeletal Remains

SAM D. STOUT, MARCELLO A. PORRO, AND BEATRICE PEROTTI  
*Department of Anthropology, University of Missouri, Columbia, Missouri 65211 (S.D.S.); Department of Scienze Antropologiche, Archeologiche, Storico Territoriali, University di Torino, Torino, Italy (M.A.P., B.P.)*

**KEY WORDS** Osteology, Clavicle, Cortical Bone, Histomorphometry

**ABSTRACT** The histological method developed by Stout and Paine ([1992] *Am. J. Phys. Antropol.* 87:111–115) for estimating age at death using the clavicle is tested on a known age independent sample from a nineteenth century cemetery near Spitalfriedhof St. Johann in Basel, Switzerland. The mean absolute difference between reported ages and histologically predicted ages is 5.5 years. Mean predicted age for the sample is different from mean reported age. This difference is accounted for by differences in the age distributions between the original autopsy sample used to derive the histological age-predicting formula and the cemetery sample, and an inherent loss of reliability of histological age predictions for the skeletal remains of older individuals. A new formula based upon the combined original autopsy sample of Stout and Paine (1992) and the Swiss cemetery sample is presented. It is recommended that this formula be used when estimating ages for older individuals or archaeological skeletal samples. © 1996 Wiley-Liss, Inc.

In 1992, Stout and Paine introduced a histological method to estimate age at death from the rib and clavicle. The broad use of any method depends upon establishing its applicability to samples independent of the one from which it was derived. The sample used to test their method for the clavicle, although different from those used to develop the predicting formulae, was small in size ( $N = 7$ ) and limited in terms of geographic origin and time depth; all were from autopsies performed in a single Midwestern county over a 1 year time period. The purpose of this paper is to report the results of a test of Stout and Paine's (1992) histological age-estimating method using an independent sample of 83 known-age clavicles from a nineteenth century Swiss cemetery.

## MATERIALS AND METHODS

The sample is from the more than 2,000 skeletal remains from a nineteenth century

cemetery near Spitalfriedhof St. Johann in Basel, Switzerland. Cross-sections were removed from the left midshaft clavicles of 83 adults (41 males and 42 females). The samples were originally obtained by one of us (M.A.P.) to generate a new predicting formula and to serve as controls for a study of the histology of cremated remains (Porro, 1994). Table 1 presents the Swiss sample's descriptive statistics as well as those for Stout and Paine's (1992) original autopsy sample. Reported ages for the Swiss sample are taken from historical records for the cemetery.

A cross-section from the midshaft of each clavicle was embedded in epoxide resins (Biodur E50), and a transverse, 65  $\mu\text{m}$  section

Received March 7, 1995; accepted November 17, 1995.

Address reprint requests to Sam D. Stout, Department of Anthropology, 200 Swallow Hall, University of Missouri, Columbia, MO 65211.

TABLE 1. Descriptive statistics for the Swiss test sample and Stout and Paine's original autopsy sample

	Swiss sample reported ages	Swiss sample predicted ages	Original autopsy ages
N	83	83	40
Mean	36.6	32.0	28.6
Minimum	17.0	16.6	13.0
Maximum	75.0	54.3	62.0
SD	15.467	9.605	12.851
SE	1.698	1.054	2.032

TABLE 2. Descriptive statistics for absolute differences between reported ages and histologically predicted ages for the Swiss and original autopsy test samples

	Swiss sample	Autopsy sample <sup>1</sup>
N	83	7
Mean	5.5 years	1.1 years
Minimum	0.04 years	0.1 years
Maximum	22.2 years	20.6 years
Standard deviation	6.548 years	9.45 years
Standard error	2.05 years	3.57 years

<sup>1</sup>Sections removed using the saw microtome are adequately thin and exhibit suitable surface quality without additional grinding and polishing.

was removed for histological analysis using a Leica 1600 diamond-saw microtome. The sections were then mounted and cover-slipped following standard histological procedures<sup>1</sup>. The sum of the intact and fragmentary osteons per unit area (OPD) was determined for each entire cross-section as described by Stout and Paine (1992) and age at death estimated using their predicting equation for the clavicle.

RESULTS

Table 1 presents descriptive statistics for predicted ages and reported ages for the Swiss sample. The mean absolute difference between reported and predicted ages is 5.5 years (Table 2). Although this is greater than the 1.1-year mean absolute difference between known and predicted ages for the small autopsy test sample reported in the Stout and Paine (1992) original article, the standard error of 2.05 years is smaller. None of the age estimates fall outside the 95% confidence interval for a single predicted value (see Giles and Klepinger, 1988). A *t*-test found the difference between the means for reported ages and estimated ages for the sample to be statistically significant ( $P = .023$ ).

DISCUSSION

Virtually all of the histological methods available to estimate age at death for skeletal remains are applicable to the long bones of the major extremities. Exceptions include the posterior border of the mandibular ascending ramus (Singh and Gunberg, 1970), the iliac crest (Weinstein et al., 1981; Boivin et al., 1981), and the rib and clavicle (Stout and Paine, 1992). There are advantages to being able to use bones other than the femur, tibia, and fibula when histologically estimating age at death. Not only can they be applied when these major long bones are not available, but they represent bones that are subjected to lower biomechanical loading, thus minimizing its effect on the histomorphometry.

The results of this study suggest that the clavicle method of Stout and Paine (1992) can provide reasonable age estimates for skeletal remains. Although the 5.5-year mean absolute difference between reported and estimated ages is acceptably low, it is problematic, especially for those involved in paleodemography, that the means for predicted and reported ages are statistically different for the sample. These contradictory findings are due to two factors: 1) differences in the age and sex distributions for the original autopsy sample and the Swiss cemetery sample and 2) limitations for histological age estimation above certain ages.

Mean ages for the original autopsy sample (28.6 years) and the Swiss cemetery sample (36.6 years) are significantly different ( $P = .005$ ), the latter being older and having a greater age range (Table 1). For the autopsy sample, one standard derivation includes the age of 41 yers, while that for the Swiss sample includes the age of 52 years, and it can be seen from Figure 1 that it is beyond the age of 40 years that the regression line for Stout and Paine's (1992) predicting equation fails to fit the Swiss data.

Stout and Paine's (1992) original autopsy sample of 40 individuals included only 8 females, while the Swiss cemetery sample includes 41 males and 42 females. In neither sample, however, was there a significant difference in OPD between the sexes.

The results described in Figure 1 can also

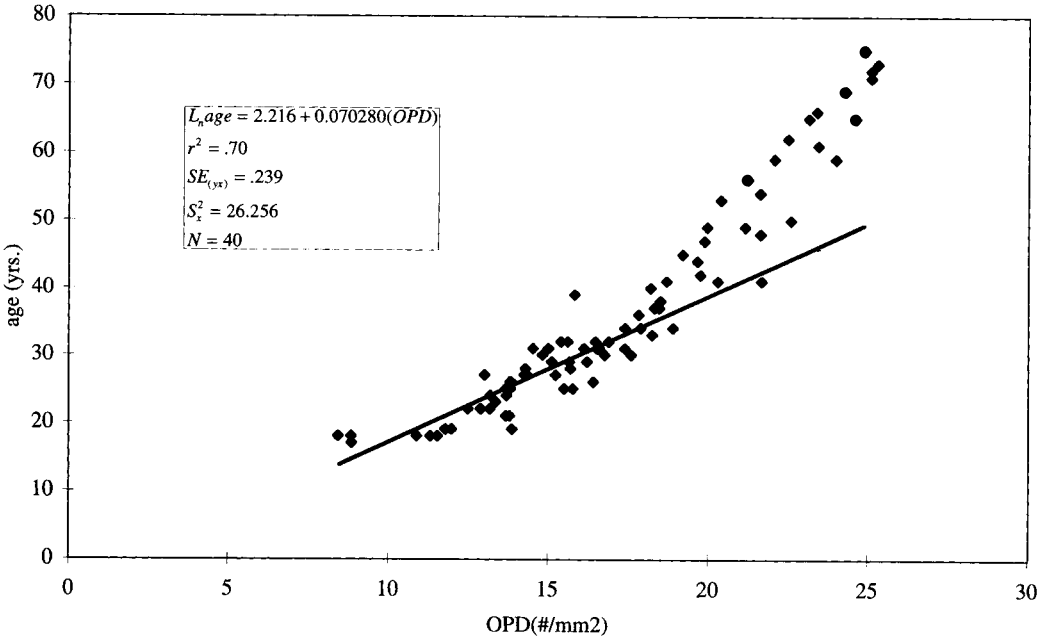


Fig. 1. Reported ages for the Swiss cemetery sample plotted against their OPDs. Solid line represents the regression line for Stout and Paine's (1992) original age estimating formula.

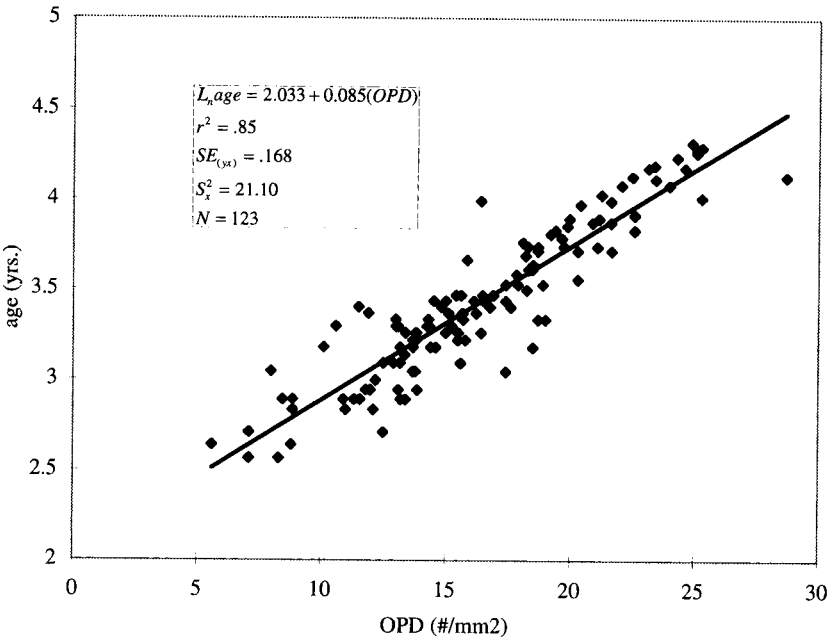


Fig. 2. OPDs against  $L_{age}$  for Stout and Paine's (1992) original autopsy sample and the Swiss cemetery sample combined. Solid line is regression line fitting corresponding to the equation fitting in the upper left fitting this data. Regression statistics are given in the upper left corner.

be explained by a loss of reliability in age prediction inherent in microscopic methods. Continuous remodeling activity eventually causes OPD to reach an asymptote when osteonal bone occupies the entire cortex and the creation of each new osteon removes the visible evidence for an existing system (Frost, 1987). Therefore, histological methods that are based upon OPD cannot reliably predict ages for bones that have reached their asymptotic value. The age at which an asymptote will be reached will vary for different bones and even for the same bone from different individuals, depending upon cortical cross-sectional area. It should also be noted that any focal or systemic factors that accelerate or decrease cortical bone remodeling rate will affect the age at which a bone reaches an asymptotic value for OPD.

In an attempt to reduce the effects of sample differences, the original autopsy and Swiss cemetery data were combined, and a new predicting equation was generated. The results are presented in Figure 2. It is recommended that this new clavicle formula, which is based upon a larger and less restricted sample, be used instead of the original equation developed by Stout and Paine (1992). It is also recommended that an age-predicting method be developed which employs a combination of bones characterized by different remodeling dynamics and cortical cross-sectional areas (e.g., clavicle (or rib) and femur).

## ACKNOWLEDGMENTS

We wish to acknowledge the assistance of Dansueli Etter, Seminar für Ur- und Frühgeschichte der Universität Basel, Abteilung Anthropologie; Andreas Cueni, Naturhistorisches Museum in Basel; and Professor Melchiorre Masali and Christiano Blandin Savoia, Dipartimento di Anthropologia, Archeologia e Scienze Storico-territoriali, University di Torino.

## LITERATURE CITED

- Boivin G, Schoenboerner A, and Baud CA (1981) Human compact bone: Structural changes with aging. *Acta Anat.* 110:81 (abstract).
- Frost HM (1987) Secondary osteon population densities: An algorithm for estimating missing osteons. *Yearb. Phys. Anthropol.* 30:239–254.
- Giles E, and Klepinger LL (1988) Confidence intervals for estimates based on linear regression in forensic anthropology. *J. Forensic Sci.* 33:1218–1222.
- Porro MA (1994) *Anthropologia E Beni Culturali. Messa A Punto Di Metodiche Istomorfometriche E Morfologiche. Ricerche In Laboratorio E Sul Campo Per Lo Studio De Reperti Osteologici Inumati Ed Incinerati. Tesi Di Dottorato Di Ricerca. Universita Di Firenze Pisa E Torino.*
- Singh IJ, and Gunberg DL (1970) Estimation of age at death in human males from quantitative histology of bone fragments. *Am. J. Phys. Anthropol.* 33:373–382.
- Stout SD, and Paine RR (1992) Histological age estimation using rib and clavicle. *Am. J. Phys. Anthropol.* 87:111–115.
- Weinstein RS, Simmons DJ, and Lovejoy CO (1981) Ancient bone disease in a Peruvian mummy revealed by quantitative skeletal histomorphometry. *Am. J. Phys. Anthropol.* 54:321–326.